Studies on the Biology of some Freshwater Fishes

PART III—*Callichrous bimaculatus* (Bloch)

BY

A. QAYYUM

Department of Zoology, Aligarh Muslim University, Aligarh

AND

S. Z. QASIM

International Biological Programme, Indian Ocean Expedition (C.S.I.R.), Ernakulam, Kerala

(*With eight figures*)

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INTRODUCTION

Callichrous bimaculatus (Bloch) is generally a fish of running water. According to Day (1878) it is found in India, Ceylon, Burma, and Malay Archipelago. It grows to about one foot in length and is highly esteemed as food. It has often been referred as 'butter fish'. During monsoon months when fields and low-lying areas get flooded, it makes an access from rivers and irrigation channels to ponds and fields. Sometimes vast numbers come up from rivers and are caught in ponds by drag-net and cast-net after the monsoon season is over. Besides September, October, and November there is no other time when this fish is caught in ponds in and around Aligarh.

No account is available on the biology of this fish excepting short descriptions on its life-history (Rao 1919), occurrence of ovigerous females and larvae in Ceylon (Deraniyagala 1930), and record of its breeding in the River Mahanadi (Job *et al.* 1955).

Methods

The fishes examined in the course of this investigation came from the local fish market. Inquiries from the fishermen suggested that they are regularly caught along with major carp, murrel, and other fish in the rivers (Ganga, Jamuna, and Kali), irrigation channels, rainwater drains, and distributaries. The gear generally employed for their capture is drag-net, small meshed gill-net, and cast-net. The present study covers a period of two years, from October 1958 to September 1960. During the first year monthly samples obtained were rather small, so the investigation was extended for another year, and for all duplicate months the data have been grouped and are presented only for a period of 12 months. Owing to scarcity of specimens, several visits to the fish market were needed to obtain a substantial number of fishes in each month. The routine examination of each fish was the same as has been used for *O. punctatus* (Part I).

Length frequency distribution

Table XIII indicates the number of fishes according to their size groups in various months. The length frequency distribution of the fish has been illustrated as histograms in Fig. 17, after pooling the sample on a quarterly basis. In the figure the various year classes that could easily be judged have also been marked arbitrarily.

The histogram for the months October-December shows five groups. Due to lack of smaller fishes in these months a clear peak representing the 0 group fishes could not be obtained. However, the fact that the smallest fishes were obtained in these months clearly shows that these belong to the current year's brood. The breeding season of the fish being July and August (see page 648), the appearance of small fishes from October to December coincides well with the inference that these could only be the 0 group fishes. The 0 group fishes being thus established, the other modes demarcated in the histograms probably represent the I, II, III, and IV year classes. The average sizes of the various year classes as determined by their respective modes are as follows: 0 group = 9·3 cm., I group = 14·0 cm., II group = 20·8 cm., III group = 24·5 cm., and IV group = 27·8 cm.

In the histogram for the other three months (January-March), the progression of these year classes can easily be followed. The length frequencies of January to March show only four groups of fishes. In these months there was a total absence of large-sized fishes and therefore the 5th mode probably belonging to four-year old fishes is

TABLE XIII

NUMBER OF FISH (*C. bimaculatus*) OF EACH LENGTH GROUP CAUGHT IN VARIOUS MONTHS

Length group	January	February	March	April	May	June	July	August	September	October	November	December
cm.												
7·0	..	..	..	..	..	..	..	..	..	..	..	..
7·5	..	..	..	..	..	..	..	..	..	..	3	..
8·0	..	..	..	..	..	..	..	..	..	..	2	..
8·5	..	..	..	..	..	..	..	..	..	..	4	..
9·0	..	..	..	1	..	..	..	..	..	..	8	2
9·5	..	..	..	1	2	2	2	..	..	..	6	4
10·0	2	..	4	..	..	3	3	..	2	3	7	8
10·5	1	..	3	2	2	..	..	1	1	1	5	9
11·0	1	..	6	3	4	5	4	3	1	4	2	10
11·5	2	1	1	2	5	7	6	1	4	5	3	11
12·0	2	..	3	6	2	2	5	..	10	3	6	8
12·5	1	..	1	1	3	..	2	5	3	8	3	6
13·0	8	..	..	1	2	4	..	5	3	7	3	..
13·5	7	..	..	1	3	..	..	7	..	9	9	1
14·0	10	..	..	2	2	2	..	8	..	2	10	1
14·5	14	..	..	1	..	3	..	2	3	11	8	..
15·0	8	..	..	3	..	..	..	4	4	10	12	..
15·5	9	..	..	1	3	1	..	3	6	10	9	1
16·0	8	7	..	..	3	..	4	..	9	5	7	..
16·5	3	..	..	2	..	..	..	..	11	..	5	..
17·0	4	2	..	1	..	3	..	1	11	..	6	..
17·5	1	..	6	2	1	6	..	1	5	1	5	..
18·0	3	..	..	2	5	1	2	2	7	3	1	..
18·5	2	..	..	1	1	..	3	2	8	..	..	..
19·0	3	..	..	1	2	2	3	3	3	2	..	..
19·5	..	..	2	..	..	3	1	3	1	..	4	..
20·0	3	2	..	1	2	1	..	2	1	1	6	..
20·5	1	..	3	..	4	..	3	..	..	..	1	3
21·0	..	..	5	..	..	3	..	1	..	..	..	6
21·5	..	..	6	..	..	2	..	2	..	..	..	4
22·0	..	2	4	1	1	4	..	4	..	..	..	5
22·5	..	1	4	..	3	1	2	1	1	..	..	1
23·0	..	2	4	3	..	..	2	..	3	..	..	1
23·5	..	1	2	..	..	2	1	..	..	..	..	2
24·0	..	1	2	3	..	..	1	1	1	..	..	3
24·5	2	2	..	..	1	..	..	..	2	..	..	1
25·0	..	3	..	..	..	2	..	..	1	..	..	2
25·5	..	1	..	1	..	..	..	..	2	..	..	..
26·0	..	..	2	..	2	..	3	..	..	..	..	1
26·5	..	1	..	..	..	1	2	1	1	..	..	2
27·0	..	1	..	..	..	..	3	..	..	..	..	1
27·5	..	..	..	..	..	..	1	..	..	..	..	4
28·0	..	..	..	..	..	1	..	..	..	..	..	3
28·5	..	..	..	..	..	1	..	2	..	..	..	1
29·0	..	..	..	..	..	..	..	1	..	..	..	..
29·5	..	..	..	..	..	..	..	..	..	..	..	1
Total ..	95	27	58	43	53	62	53	66	104	85	135	102

lacking. The average size of the preceding year classes 0 to III is approximately 11·2, 15·8, 21·0, and 25·2 cm. respectively.

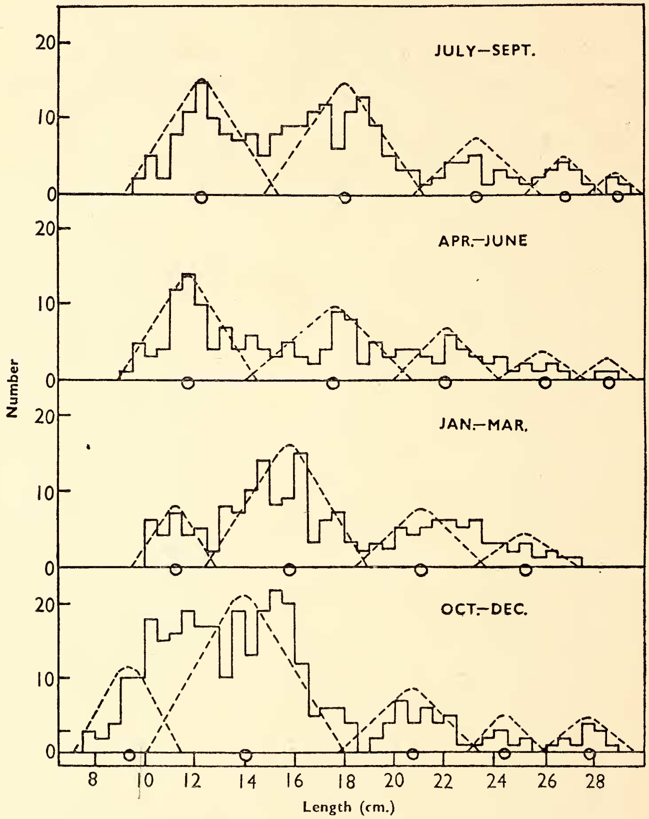

Fig. 17. Length frequency distribution of *C. bimaculatus*

Open circles denote average length of various year classes as indicated by modes. Modes marked by broken lines.

In the histogram for April to June there are five modes representing 0, I, II, III, and IV year classes. Their average size is 11·7, 17·5, 22·0, 26·0, and 28·5 cm. respectively.

The histogram representing July to September also shows five distinct modes. The first with a modal size at 12·2 cm. has just completed one year as they were born during the corresponding period of the preceding year. Similarly in other year classes which have reached the end of each year's life, the sizes attained are as follows: 2nd year = 18·0 cm., 3rd year = 23·2 .cm., 4th year = 26·8 cm., and 5th year = 28·9 cm.

Table XIV

Average length of various Year Classes of *C. bimaculatus* obtained from the Length Frequency Distribution of various quarters together with the Size Range of each Year Class

Year classes	Months	Range in size, cm.	Average length, cm.
0	October-December	7·2-11·4	9·3
	January-March	9·5-12·8	11·2
	April-June	9·0-14·5	11·7
	July-September	9·2-15·3	12·2
1	October-December	10·0-18·0	14·0
	January-March	12·0-18·9	15·8
	April-June	14·0-20·8	17·5
	July-September	14·8-21·0	18·0
2	October-December	17·8-23·4	20·8
	January-March	18·4-23·7	21·0
	April-June	19·9-24·2	22·0
	July-September	20·8-25·7	23·2
3	October-December	22·9-26.0	24·5
	January-March	23·2-27·2	25·2
	April-June	24·0-27·6	26·0
	July-September	25·3-28·2	26·8
4	October-December	25·8-29·7	27·8
	January-March	— — —	—
	April-June	27·1-29·6	28·5
	July-September	27·8-29·7	28·9

Table XIV gives the average sizes of each year class as revealed by the quarterly histograms in various seasons. It is evident from the table that the increase in length during the first year is about 12 cm. During 2nd, 3rd, 4th, and 5th years the increases in length are 6·0, 4·5, 4·0, and 2·5 cm. respectively. In the first year the growth rate is considerably fast. It slows down progressively in subsequent years. In all size groups, growth continues to occur throughout the year.

Breeding

(a) Stages of maturity

All fishes were sexed and grouped according to the conventional five maturity stages (see Part I). During maturation the gonads of

TABLE XV

MATURITY STAGES IN VARIOUS LENGTH GROUPS OF *C. bimaculatus*

Maturity Stages		Length in cm.→ 7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0	23.0	24.0	25.0	26.0	27.0	28.0	29.0
Male	I.	2	5	16	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	II.	..	..	..	15	17	12	21	25	27	14	12	5	3	8	5	4	2	3	1	1	..	..	..
	III.	..	..	..	1	2	6	2	2	4	3	2	3	..	1	2	1	2	1	..	1	..	..	..
	IV.	..	..	..	5	14	4	1	2	2	2	5	5	8	3	5	4	2	..	..	1	..	..	..
	V.	..	..	..	1	2	9	..	..	8	8	7	6	5	1	..	2	1	1	1	1	..	..	..
Female	I.	1	1	12	31	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	II.	..	..	..	2	33	34	23	31	32	21	13	4	8	12	11	12	10	6	5	6	6	4	2
	III.	..	..	..	..	8	1	5	3	3	2	2	3	2	5	3	3	1	3	1	..	..	..	..
	IV.	..	..	..	..	12	10	14	11	3	2	6	4	4	2	3	6	2	2	2	5	4	4	..
	V.	..	..	..	..	3	4	4	5	5	12	9	13	3	2	..	3	3	2	2	1	..	4	..

this fish undergo marked changes in form, colour, etc. which can be summarised as follows: In immature fishes (Stage I) the ovaries are small, sausage-shaped, translucent, and buff-coloured, while the testes are ribbon-like, white, and transparent. The maturing virgins or recovered spent fishes (Stage II) have enlarged, sac-like, translucent, and dull-pink-coloured ovaries. In these fishes the eggs are invisible to the naked eye. The testes are slightly coiled, white, and translucent. In ripening fishes (Stage III) the ovaries are considerably enlarged, opaque, and light yellow in colour. Eggs in females become visible to the naked eye while in males the testes are opaque, distinctly coiled, and white. In ripe fishes (Stage IV) ovaries are very much distended and occupy the entire body cavity. They are yellow in colour and contain large opaque eggs. In males the testes are greatly coiled, opaque, and pale white. In spent fishes (Stage V) ovaries are collapsed, flesh-coloured, while the testes are shrunken and dull-white.

(*b*) *Size at first maturity*

The various size groups falling in each maturity stage throughout the period of observation are given in Table XV. It can be seen from the table that, in both sexes, all fishes up to 9 cm. were classed as immature. In 10 cm. group higher stages of maturity begin to appear. In males all the five stages were seen in this size group but in females there was no further advance beyond stage II. At 11 cm. length in females all maturity stages from II to V were recorded. It therefore appears that males mature at a size smaller than the females. The smallest ripe male and female were of 10·3 cm. and 11·1 cm. respectively. If these sizes are compared with the length frequency distribution it would appear that both sexes attain maturity when they have completed the first year of life.

(*c*) *Sex ratio*

The ratio between females and males was 1:0·65, as out of the total of 881 fishes sexed 532 were females and 349 were males. If the sex ratios are examined from month to month practically the same figure is obtained, indicating that this ratio remains more or less persistent throughout the year. The largest male was 26·0 cm. and female 29·5 cm. This suggests that either the longevity in males is less or they grow at a relatively slower rate.

(*d*) *Spawning cycle*

The number of fishes at each of the five maturity stages are shown month by month in Table XVI and the monthly percentages are illustrated diagrammatically in Fig. 18. It can be seen from the figure that gonads show a regular seasonal change and that there is hardly any overlap between various maturity stages. The gonads of all fishes

TABLE XVI

NUMBER OF FISH (*C. bimaculatus*) AT EACH OF THE FIVE MATURITY STAGES IN EACH MONTH

Month	Sex	Maturity Stages					Total
		I	II	III	IV	V	
July	Male	..	..	..	18	3	21
	Female	4	..	..	25	3	32
August	Male	..	..	..	15	4	19
	Female	..	..	..	35	12	47
September	Male	..	..	..	..	46	46
	Female	2	..	..	..	56	58
October	Male	2	39	..	..	..	41
	Female	2	42	..	..	..	44
November	Male	18	42	..	..	..	60
	Female	14	61	..	..	..	75
December	Male	4	22	..	..	..	26
	Female	11	65	..	..	..	76
January	Male	..	42	..	..	..	42
	Female	3	48	..	..	..	51
February	Male	..	9	..	..	..	9
	Female	..	18	..	..	..	18
March	Male	..	17	3	..	..	20
	Female	..	35	3	..	..	38
April	Male	1	4	13	..	..	18
	Female	3	6	16	..	..	25
May	Male	..	..	17	5	..	22
	Female	3	..	26	2	..	31
June	Male	..	..	..	25	..	25
	Female	3	..	..	34	..	37
Total	Male	25	175	33	63	53	349
	Female	45	275	45	96	71	532

which are likely to spawn during the forthcoming breeding season recover fully in February and March. This is soon followed by the ripening stage in April and May. In June most of the fishes are ripe, and from July spent fishes begin to appear. In August the proportion of spent fishes increases, and by September the entire population contains nothing but spent fishes. The occurrence of spent fishes in late July shows the commencement of spawning in this month. Their progressive increase in August and September and the total absence of ripe fishes in September indicate that the spawning is restricted to July and August only.

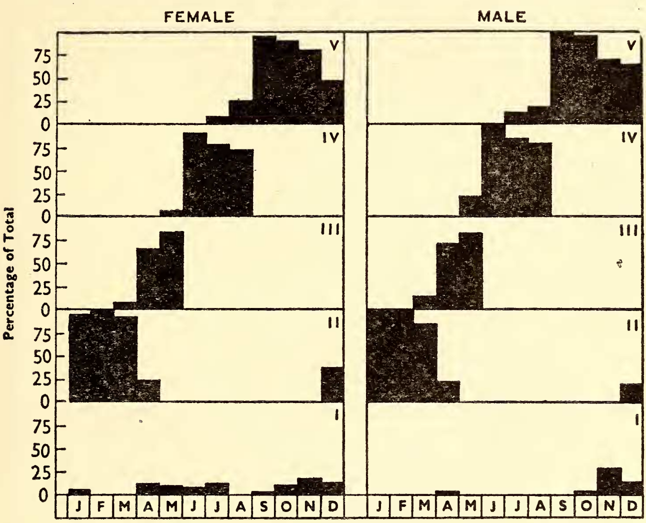

Fig. 18. Monthly percentages of *C. bimaculatus* at each of the five maturity stages during different months

(*e*) *Seasonal changes in gonad weight*

Seasonal changes in the gonad weight of both sexes were also recorded. These have been given in Fig. 19 as percentages of body weight. In the testes there was no significant change in weight until May. The maximum weight of testes was recorded in June when they were mostly ripe and from July there was a decline in testes weight, which reached its minimum in September. After September there was hardly any rise in testes weight until the following April.

In females the slow recovery of the ovaries was accompanied by no change in weight until December. In January the ovaries begin to gain weight, and from April to June there occurs a tremendous change in their size and weight. The maximum figure is rapidly attained in June, from July the decrease in weight becomes obvious, and by

September it reaches its minimum. Such a rapid rise in the weight of the ovaries and its sudden fall during the two months (July and

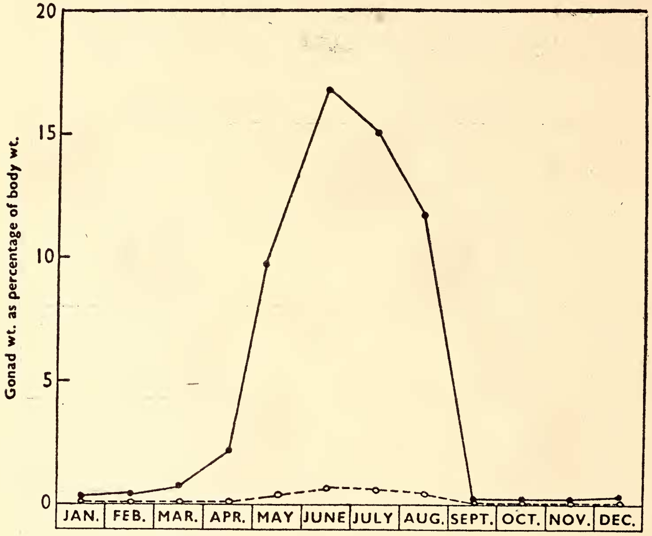

Fig. 19. Seasonal variation in the gonad weight as percentage of body weight of *C. bimaculatus*

Of females, continuous line ; of males, broken line

August) give a clear indication that the spawning season is very short and in all probability lasts for two months only, July and August.

(f) Spawning periodicity

Ova diameter frequencies have indicated that the ovaries of this fish contain a single group of eggs. In ripe fishes this group of large oocytes is widely separated from the much smaller yolkless cells (Qasim & Qayyum 1961). To determine whether all the large ova are shed in one spawning act or whether there is a spawning periodicity, the progression of the intra-ovarian eggs was studied during the pre-spawning and spawning months. Ova diameter frequencies from April to June are given in Fig. 20. It can be seen from the figure that in April, when fishes have reached the ripening stage, the stock of ova which are likely to be spawned during the forthcoming breeding season begins to get differentiated. The size of all these ova ranges from 0·5 to 0·85 mm. In May the single batch thus demarcated gets more distinct, and in June when fishes attain peak maturity this batch becomes widely separated from the immature eggs which probably form stocks of later years. The size of the ripe ova ranges from 0·75 mm. to 1·25 mm. Spent fishes obtained in late July contain no eggs in their ovaries besides the immature eggs which measure about 0·25 mm. This clearly indicates that the entire batch of ripe ova is spawned and that there is no possibility of each individual spawning more than once during the breeding season. As has been noted elsewhere (Qasim & Qayyum 1961) in all such fishes where

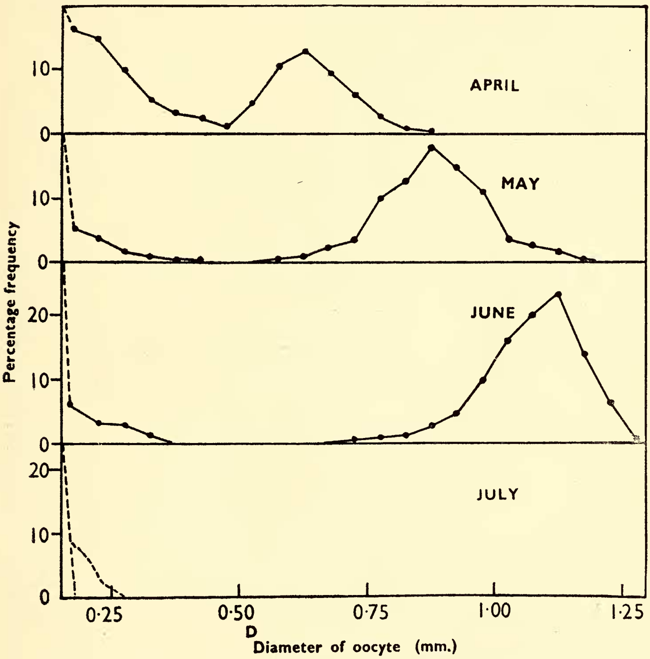

Fig. 20. Size frequency distribution of maturing oocytes of *C. bimaculatus* from April to July

a single group of ova is matured and shed, the duration of spawning in each individual is very short. Since the spawning of all the individuals of the population is well synchronised, the spawning season of the species lasts only for about two months.

(g) Condition factor

The formula for calculating the 'condition factor' of the fish was the same as used in *O. punctatus* and *B. stigma,* i.e. $K = \frac{W \times 100}{L^3}$. The K value of each fish in each month was calculated and the data for all the individuals in various months were pooled to find the arithmetical mean values of each size group and for each month. The former have been plotted in Fig. 21 and the latter in Fig. 22. It is clear from Fig. 21 that with the increase in length the K values continue to increase up to 20 cm. in males and up to 22 cm. in females. From these size groups onwards there is a progressive decline in the K values of both sexes. The points of inflection in the curves of both sexes, at 20 cm. in males and 22 cm. in females, do not correspond to the size at first maturity as determined by the changes in the gonad maturity. That the secondary decline in large fishes is due to increasing metabolic strain of spawning as has been

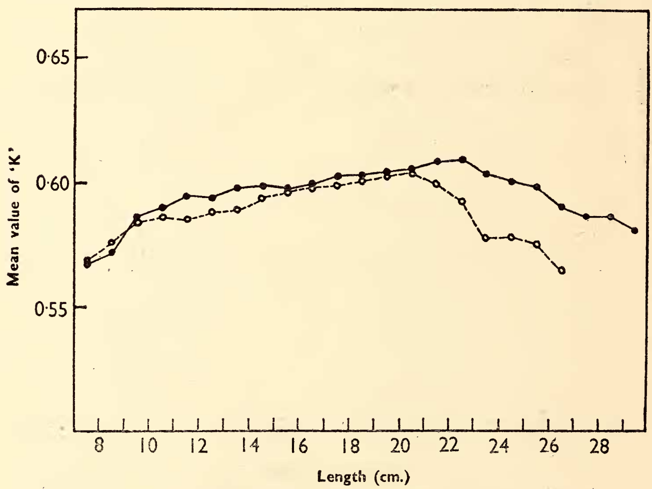

Fig. 21. Mean condition factor (K) of *C. bimaculatus* at different length groups

Of females, continuous line ; of males, broken line

indicated in many other species (Hart 1946; Menon 1950) seems very likely. Because, if the rate of increase of K with the size of fish is taken as a criterion of 'metabolic strain', then it would appear from the figure that after the maturity is attained, which is at 10-11 cm., the increase in K becomes less rapid. A similar feature in the condition factor has been noticed in *O. punctatus* (Part I).

Fig. 22 gives the monthly K values of both sexes. In calculating the mean, immature fishes which were smaller than 10 cm. have been omitted from the sample. As can be seen from the figure, in females the seasonal cycle of condition factor is better defined than in males (Fig. 22). Maximum K value for females is obtained in June which corresponds to the maximum figures recorded for the gonad weight. Its decline in July, August, and September seems entirely due to spawning. In males, on the other hand, maximum K value is obtained in May. This does not correspond entirely to changes in the gonad weight because the gonad weight is highest in June. Probably it is because of general building up of reserves before spawning that the K value records its highest in May. A decrease in K value in June when peak maturity is attained is presumably because of utilisation of body reserves towards gonad building in males. The cycle of the condition factor seems entirely connected with the maturation of the gonads and spawning in both sexes however.

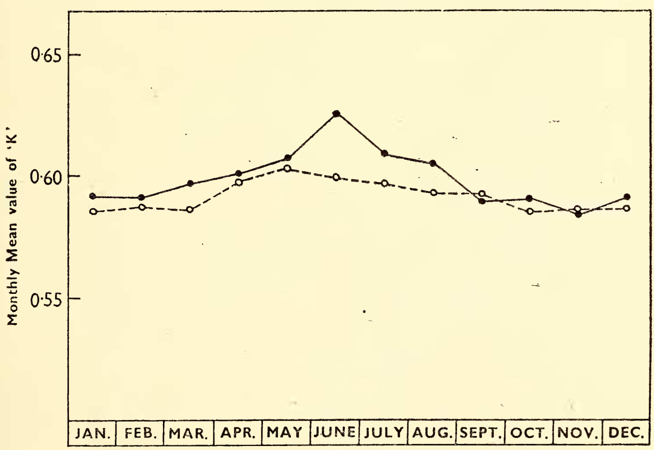

Fig. 22. Seasonal variation in condition factor (K) of *C. bimaculatus*
Of females, continuous line ; of males, broken line

Food

(a) Food of all size groups

Nothing is known about the food of *C. bimaculatus*. The present investigation which is based on the gut content analysis of 881 fishes

TABLE XVII

PERCENTAGE OCCURRENCE OF VARIOUS CATEGORIES OF FOOD IN THE GUTS OF *C. bimaculatus*

Months→	January	February	March	April	May	June	July	August	September	October	November	December
No. of fish examined..	93	27	58	43	53	62	53	66	104	85	135	102
No. of fish with food..	57	19	39	31	39	43	31	38	97	76	98	66
Barbus ticto ..	38·5	47.3	53·8	58.0	48·7	41·8	25·8	26.3	37·1	64·4	56·1	46·9
B. conchonius ..	25·0	15·6	28·1	25.8	22·8	6.9	28·9	42·0	52·0	31·4	71·3	24·1
B. stigma ..	..	..	..	12.9	20.5	9·3	..	..	14·4	..	..	..
E. danricus ..	..	5·2	..	12.9	..	11·6	..	..	..	..	..	..
Chela sp. ..	..	..	..	3.2	..	..	..	..	..	..	..	..
Trichogaster sp. ..	..	..	2·5	..	..	2·3	3·2	..	..	..	..	..
Mystus sp. ..	..	..	..	..	..	..	..	..	1·0	..	..	..
Amblypharyngodon sp.	..	..	..	..	..	..	3·2	..	1·0	1·3	..	..
Rohtee cotio ..	..	..	..	..	..	..	6·4	2·6	2·0	..	1·0	..
Digested fish ..	3·5	..	4·7	..	5·0	2·3	..	..	6·0	3·9	8·1	6·0
Orthoptera ..	..	..	..	..	..	..	32·2	44·7	16·3	23·6	26·5	6·0
Hymenoptera ..	9·3	..	..	..	..	..	19·3	23·6	22·2	26·2	16·3	3·0
Coleoptera ..	7·0	5·2	..	13·0	2·5	4·6	6·4	10·5	5.1	2·6	6·1	3·0
Odonata ..	14·0	20·8	4·7	6·5	2·5	..	..	..	3·1	5·2	..	3·0
Hemiptera ..	1·7	5·2	7·5	6·5	4.7	4·6	6.4	7·8	..	..	2·0	4·5
Ephemeroptera ..	..	..	..	..	..	..	..	2·6	1·0	..	..	3·0
Plecoptera ..	..	..	..	6·5	2·5	..	..	..	..	..	..	..
Digested insects ..	1·7	..	4·7	12·9	2·5	2·3	..	2·6	4·0	3·9	2·0	..
Mucous ..	..	..	9.4	..	..	..	1·6	2·6	5·1	7·8	10·2	4·5
Prawn ..	3·5	10·4	4.7	3·2	2·5	..	3·2	..	1·0	1·3	..	..

clearly illustrates the nature of the food and its variation from month to month. Out of the total number of fishes examined, 267 had no food in their guts. The percentage composition of various items of food in the gut from month to month is given in Table XVII. As

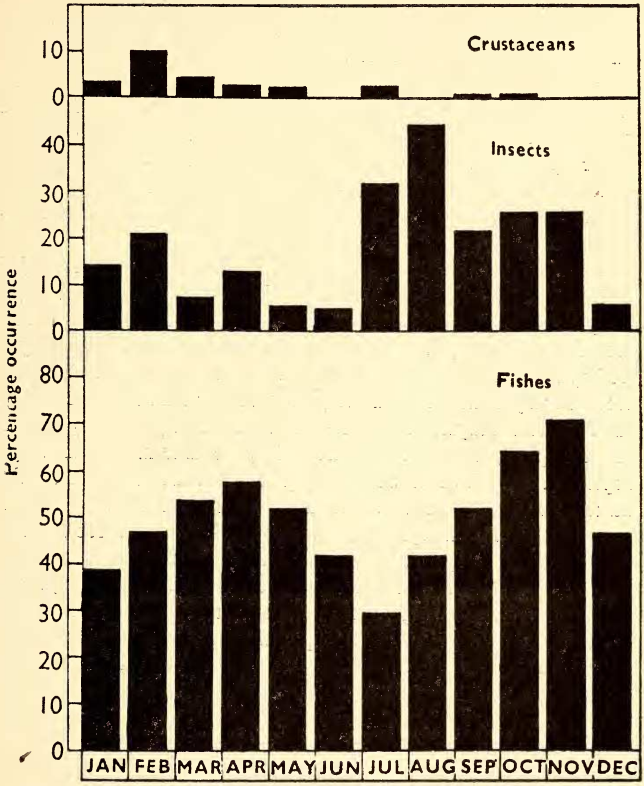

Fig. 23. Relative occurrence of three important food items of *C. bimaculatus* in different months

can be seen from the table, fish and insects form the main food. The occurrence of these two groups in various months is shown in Fig. 23, together with crustaceans (prawns) which form food of lesser importance.

Fish occurred in nearly 66% guts. Maximum numbers containing fish were recorded in October and November. In these months, sometimes as many as six fishes were found in a single gut. From April to July the occurrence of fish in the gut progressively falls. This may be connected with the maturation of gonads, because in *C. bimaculatus* April to July are the main months when peak maturity is attained. Probably during this period the fish becomes less active and fails to catch other fishes.

In all, nine species of fish were recorded from the guts. Of these, *Barbus ticto* and *B. conchonius* were most abundant. The former occurred in the largest number of guts whereas the latter came next. Other species ingested were *B. stigma, Esomus danricus, Chela* sp., *Trichogaster* sp., *Amblypharyngodon mola, Mystus* sp., and *Rohtee cotio*. These were relatively in small proportions and occurred only in some months of the year (Table XVII).

Insects formed the other important item of food. These included both terrestrial and aquatic species. Terrestrial insects were grasshoppers, ants, and beetles, whereas aquatic insects belonged to the Orders Coleoptera, Odonata, Hemiptera, and Ephemeroptera. Orthopterous insects were not regularly found in the gut. They were recorded only in the monsoon and post-monsoon months (July-December). In July and August they were found in nearly 40% guts. Ants (Hymenoptera) also occurred from July to December. In August, September, and October ants were quite abundant in the guts. Some fishes contained as many as 30 ants. Terrestrial beetles were comparatively rare although they did occur in the monsoon months. Aquatic beetles (Dytiscidae), on the other hand, occurred practically throughout the year. The occurrence of terrestrial insects (grasshoppers, ants, and beetles) in a large number of guts was at first rather surprising but, since they started appearing from the monsoon months, it became obvious that they must have been carried to the rivers from land along with the rain-water.

The other aquatic insects such as dragonfly nymphs occurred in small proportions, but during winter months (January and February) they became fairly common in the gut. *Corixa* sp., *Notonecta* sp., and *Gerris* sp. formed the aquatic hemipterous group of insects. *Corixa* and *Notonecta* were common throughout the year. Occasionally *Gerris* and *Hydrophylid* insects were also seen. Ephemeroptera nymphs and Plecopterous insects were also recorded in a few guts on two or three occasions.

Crustaceans were rarely seen in the gut. The only organism which made frequent appearance in the diet was prawn. Since it appeared as fragments or as digested remains it was impossible to identify the species.

The nature of the food of *C. bimaculatus* clearly shows that this fish is highly predaceous and subsists mainly on fish and insects. In *C. pabda,* which is closely related to *C. bimaculatus* systematically, some investigations have been made on the food. According to Mookerjee *et al.* (1946b), its food in Bengal consists of algae, protozoans, and crustaceans. The same fish at Lucknow has been found to feed on insects, fish, higher aquatic weeds, molluscs, unicellular algae, and crustaceans (Das & Moitra 1955). The food for *C. bimaculatus,* therefore, differs considerably from that of *C. pabda* as no aquatic weeds, algae, or molluscs were recorded during the present investigation.

From the various items of food ingested it appears that *C. bimaculatus* is more or less a surface feeder. Since its food includes a variety of fishes, it seems that this species is capable of feeding in the entire pelagic zone. The rarity in the gut of crustaceans and other organisms which are otherwise common in rivers provides some evidence that *C. bimaculatus* is a selective feeder.

(*b*) *Seasonal variation in the rate of feeding*

The feeding rhythm of the fish in different months has been shown in Fig. 24. It can be seen from the figure that two periods of intensive feeding are clearly marked. One lasts from September to November and the other from March to June. The only time when feeding

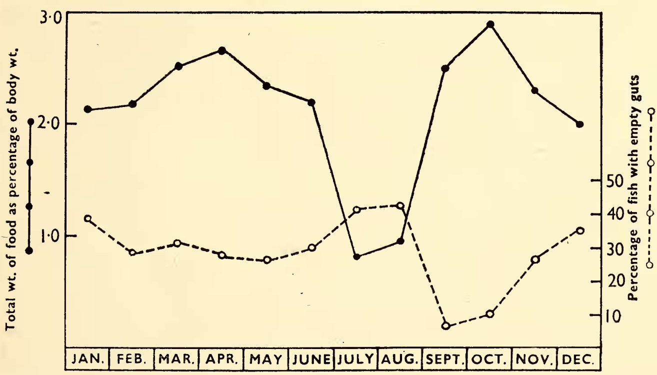

Fig. 24. Seasonal variation in the rate of feeding of *C. bimaculatus*

showed a considerable reduction was during July and August. These being the spawning months, the marked reduction in feeding is probably due to peak maturity and spawning. The other time when feeding shows a slight decrease is from December to February. This may have been due to the low temperature conditions prevailing in the winter of northern India.

Freshwater environment and the biology of fishes

In India freshwater environment provides great diversity in physical, chemical, and biological conditions from season to season and from one part of the country to the other. Whether it is a lotic (running) or a lentic (static) environment, the biotic potential of any body of water depends upon its standing crop of organisms. These organisms are mainly composed of five large groups: (1) phytoplankton, (2) bottom flora, (3) bottom fauna, (4) zooplankton, (5) fishes. The first two constitute a producing cycle and the other three form a consuming cycle (Welch 1952). These features establish a complex interrelationship in the form of a nutritional chain in water (Darnell 1958, 1961).

In India the inland waters are teeming with life (George 1961) but, since no estimations have been made of the total productivity, it is difficult to say how it would vary in a given time or from one environment to the other. The work that can be carried out on plants and animals of a freshwater environment is of great significance and will go a long way towards reaching an understanding of the complex interrelationship between animal and plant communities. There are indications that these relationships may eventually change into mathematical aggregates (Lindeman 1942; Hazelwood & Parker 1963). At present owing to the newness of the subject it is difficult to attempt any generalisation and whatever is said must be regarded as only suggestive.

The foregoing accounts of the biology of three species (Part I-III) indicate that fishes, whether living in ponds or rivers, undergo progressive and predictable changes. Some of these changes are inevitable and inherent and could be appraised by carefully planned studies. Out of the three species investigated, two (*O. punctatus* and *B. stigma*) came from ponds and the third (*C. bimaculatus*) came from rivers. The pond fishes were particularly favourable material for research because they were not only common but easy to collect in fairly large numbers at all times of the year and practically all stages in their lives.

In all the three species, the length frequency distribution gave evidence of modes probably representing various year classes, on the basis of which an estimate of the growth rate could be made. Breeding in each species was adapted to an annual rhythm. The cycles of maturation and depletion of the gonads were fairly regular and were repeated almost at the same time every year. Each species attained maturity by the end of the first year of life. The duration of their breeding was dependent upon the frequency of spawning. In *O. punctatus* which spawned repeatedly the breeding season was long, whereas in the other two species, *B. stigma* and *C. bimaculatus*, each individual spawned once only and their breeding seasons were relatively short. Breeding in ponds was non-synchronous. In some ponds the spawning occurred earlier during the season, whereas in others it was delayed or even inhibited. Probably the amount of repressive factor present in ponds (Swingle 1956) governed the spawning of fishes. Breeding seasons, however, coincided with monsoon and post-monsoon months. Feeding rhythm in all the species varied from season to season. The quality and quantity of the food consumed was influenced by physical factors (temperature and rainfall) and biological factors (gonad maturity and spawning). The food of *B. stigma* consisted of plankton organisms, algae, and organic debris. *O. punctatus*, though it fed on other aquatic organisms and fishes, showed a strong preference for *B. stigma*. *C. bimaculatus* fed chiefly on forage fishes including *B. stigma*.

It is therefore evident that in an environment for the maintenance of life processes a fish becomes a part of the complex interrelationship between animal and plant communities. Such a relationship has already been described in many tropical lakes (Fryer 1959). In a static environment (pond) a fish population gets very limited by interspecific competition which may be for food, for space, or for breeding (Rounsefell & Everhart 1953). In tropical latitudes the fauna and flora of a freshwater environment are extremely diverse (Hickling 1961, 1962). Their qualitative and quantitative variations are dependent upon seasonal exigencies such as winter, summer, and monsoon.

Age determination

While this work was in progress, no method of age determination was known in any of the species under investigation. The authors therefore conducted their studies on the growth of each species entirely on the basis of length-frequency distribution. Since the work was completed, the occurrence of growth zones on the opercular bones of

O. punctatus has been discovered (Qasim & Bhatt 1963) and it may be of interest to note that the mean lengths of the various year classes determined by the zones of the opercular bones agree closely with the average sizes determined from the various modes of the length-frequency distribution (Table II, at **61** (1) : 79). So the deduction made in this paper that the various modes correspond to year classes, at least in *O. punctatus*, seems correct.

Summary

Studies on the biology of three common freshwater fishes, namely *Ophicephalus punctatus*, *Barbus stigma*, and *Callichrous bimaculatus*, have been described in three different parts as follows:

I. *Ophicephalus punctatus*

A close examination of the length frequency curves, based on quarterly data, revealed distinct modes which evidently correspond to three or four year classes. By taking the average size of each year class, the growth rate of the fish can be estimated. Growth seems rapid during the first year. It slows down progressively in subsequent years as the fish grows older.

Both sexes mature when 11 cm. in length and begin to spawn when about one year old. The breeding season lasts from June to October. Testes are subjected to far less changes in weight than the ovaries. The maximum weight of the gonads in both sexes is obtained in June which corresponds to peak maturity. The ovaries of maturing fishes show two groups of ova which are expelled from the ovaries successively during the spawning months. Larvae are of common occurrence from July to October.

The values of the 'condition factor' (K) increase with the length of the fish up to 19 cm. From then onwards there is a secondary fall in the K values of both sexes. A seasonal cycle in the condition factor is well defined in both sexes. High and low values obtained in the various months correspond to seasonal changes in the gonad condition and feeding rhythm of the fish.

The food of *O. punctatus* varies according to the size of the fish. The adolescent and older fishes feed on fish, insects, and other aquatic organisms. Immature fishes consume mainly insects and crustaceans. The larvae of this species are mainly plankton feeders.

The total intake of food in larger fishes varies in different months. There are two periods of active feeding each year. Immature fishes continue to feed practically at the same rate throughout the year.

II. *Barbus stigma*

Length frequency distribution of *B. stigma* discerns at the most two to three year classes. A progression of these year classes in various quarterly seasons has been studied to determine the growth of the fish.

The fish attains sexual maturity when about 7·0 cm. in length. At first maturity the males are generally smaller than the females. The spawning season lasts from June to September. There is a single group of ova present in the maturing ovary which suggests that the cycle of spawning in each individual occurs only once a year. The condition factor of the fish increases with the increase in length and there is no secondary decline in large-sized fishes, which may be attributed to the onset of maturity. In both sexes there is a regular seasonal cycle in the condition factor which seems to be governed by the seasonal changes in gonad weight.

The food of the fish consists of a variety of animal and vegetable organisms. Organic debris, sand, and mud are also ingested in large quantities. There is no marked difference in feeding intensity from season to season. The fish feeds actively in all months of the year excepting November and December when there occurs a slight decrease.

III. *Callichrous bimaculatus*

Modes representing four to five year classes can be recognized from the quarterly size frequency histograms. The growth in length in the first year is about 12 cm. whereas during the 2nd, 3rd, 4th, and 5th years it is approximately 6·0, 4·5, 4·0, and 2·5 cm. respectively.

Both sexes spawn for the first time after they have completed their first year of life. Males at this age attain a length of 10 cm. and the females about 11 cm. The spawning season is short and lasts for about two months, July-August. Both sexes show regular seasonal changes in their gonads and the spawning is well synchronized throughout the population. Ova-diameter frequency distribution reveals only one group of oocytes in ripening and ripe ovaries which seems to be shed in a single spawning act. The seasonal cycle in the 'condition factor' is better defined in females than in males. The maximum value for males is obtained in May and for females in June. The mean K values obtained for each length group gave some indication of the size at first maturity.

The food of this species consists of fish and insects. There are two periods of intensive feeding. The minimum quantity of food is consumed in July and August when most of the fishes have ripe gonads.

The interrelationship of fishes and freshwater environment is discussed in the light of studies on the biology of *O. punctatus, B. stigma,* and *C. bimaculatus.*

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